Toward an Automated Assessment Method of Manual Dexterity

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***Abstract*— RoboHealth is a project that is focused on giving assistance to medical staff in order to improve the quality of treatment provided to patients in rehabilitation processes. The project covers two aspects during the rehabilitation process: assessment and therapy itself. In previous work [1], an automatic assessment system was presented for the evaluation of patient progress and effectiveness of the therapy, that is based on the Box and Blocks Test (BBT) of manual dexterity. In this article, an extension of the first trials including more participants is presented. This further advocates the use of automated methods in physical rehabilitation assessment.**

I. INTRODUCTION

Since rehabilitation is a laborious process of expensive intervention, evaluating its therapeutic effectiveness is particularly important [2]. This assessment is commonly performed by health professionals themselves, using standardized scales in order to have objectivity in the evaluation, but which are subject to the subjectivity of the observer. In some cases, the evaluation methods are composed of well-defined exercises based on numerical scales, which may be susceptible to be automated. Thus, an objective assessment of the physical condition of the subject to be treated is obtained. In addition, the rehabilitator is provided with more time to assess the results, and based on them, correct the therapy method applied, change the level of difficulty or analyse the process.

For a rehabilitation process to be automated, the method to extract metrics and the degree of acceptance by both users and health professionals should be assessed. To design assistance rehabilitation systems, although the focus is on the subject to be treated, it is important to systematize the understanding of the requirements demanded by therapists in order to enable an easier integration of technology in their daily activities [3]. Regarding the method, those tests that are administered without direct contact of the professional are more susceptible to be automated. Concerning metrics, it is essential to assess which ones give relevant information and are less invasive for the subject to be evaluated [4].

II. MATERIAL AND METHODS

A. The Box and Blocks Test

BBT is a clinically validated system for the individual measure of gross manual dexterity and coordination. The test consists of a wooden box with two 290 mm side length square compartments, and 150 wooden cube-shaped blocks of 25 mm. A 100 mm high partition located between the two compartments must be overcome with the user's hand to count the block as valid. The objective of the test is to transport from a one compartment to the other the maximum number of blocks in one minute. For the score, the therapist must count the number of cubes transported. The development of the test includes three stages: a 15-second trial prior to testing; the procedure done with the dominant hand (unaffected) in one minute, and finally the procedure executed with the non-dominant hand (affected) in one minute. When testing begins, the subject should grasp one block at a time, transport the block over the partition and release it into the opposite compartment to score. The rules and the instructions for the examiner and the subject are available in [5].

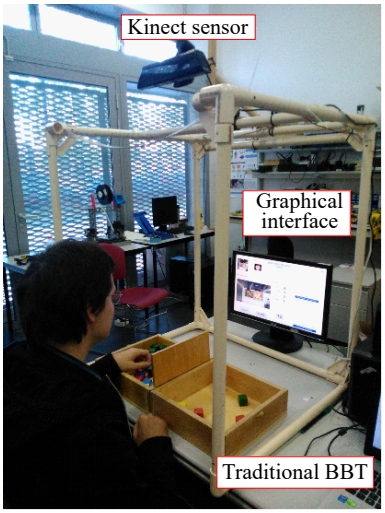

Fig. 1: Setting for the ABBT at the Assistive Robotics Laboratory at the UC3M.

B. Automating the traditional method

The proposed system in [1], named as the Automated Box and Blocks Test (ABBT) has two targets: to automated the scoring of the traditional BBT, and to enable the autonomous test administration, with the minimal participation of medicals or without it.

To address the first aim, a Kinect® for Windows® sensor is placed on top of a lightweight cube-shaped structure (Fig. 1). This sensor is used for monitoring the test development and for detecting the cubes displaced. The data acquired is processed on Matlab®. To count the blocks, first the border

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TABLE I: Demographics of the participants and trial results

Participant	Age	Affectation	Gender	Total score*	
				DH	NDH
Subject 1	23	Left-sided hemiparesis	Male	35 / **44**	28 / **32**
Subject 2	54	Akinetic-rigid syndrome	Female	45 / **56**	37 / **49**
Subject 3	55	Right-sided hemiparesis	Female	36 / **50**	11 / **11**
Subject 4	58	Right-sided hemiparesis	Male	33 / **54**	3 / **3**
Average of ABBT detection success rate:				73%	91%

*Scoring for the ABBT and the BBT (bold) grouped by dominant hand (DH) and non-dominant hand (NDH)

of the box is detected by using the depth data and a heigh threshold. Based on that, both the left and right compartments are identified. A region of interest (ROI) is cropped from the color frame according to the evaluated hand. A series of morphologycal operations (opening, closing, erosion) are applied to the ROI to detect the cubes.

The automatic test administration is addressed through a graphycal interface, which guides the subject during the test developing. Also, it is able to show and to record results.

At laboratory, the success detection rate was of 100 % up to 25 blocks, that improves a similar work in [6]. In order to evaluate the performance of the ABBT in a real situation, an extension of the first pilot trial but with more individuals was conducted at a healthcare facility.

III. RESULTS

Four subjects with diferent levels of upper limb impairments were selected by medical professionals. The participants were chosen according to the following inclusion criteria: a) Affectation of the upper extremity, b) Gripping ability, c) Spasticity according to Modified Ashworth Scale $\leq$ 2, and d) Ability to understand Mini-mental test instructions $\geq$ 24.

Participants were proposed to use the ABBT alone, without help of therapist. Namely, the test was administrated automatically. Demographics data of the participants in the trial are shown in Table I. Also, a comparative between the scoring obtained by using the traditional method (BBT) and by using the automated method (ABBT) is shown (the two last columns on the right side). This results are grouped by dominant hand and non dominant hand.

It can be seen that the success rate was different depending on whether the exercise is performed with the unaffected or affected hand. For the first case, the average of the success rate in the detection of cubes was 73%, while for the second case, the average was 91%. On the one hand, this difference is due to the greater speed of movement with the healthy hand, and that makes difficult the detection of the cubes. On the other hand, the variations in environmental conditions also add some error when working with color segmentation.

IV. DISCUSSION

The manual score of BBT not only requires to obtain the total number of cubes, since they could be counted at the end of the test, but also that the attempts must be valid (hand overcome the central barrier, not to move more than one cube at the time). These requirements are addresses in the ABBT implementation to allow the therapist to focus attention on the subject movements and to evaluate the way that the test is performed. Thus, additional information is obtained which could be limited by using the traditional method. Even more, ABBT itself acquires extra information such as the time in which the cube has been detected. The analysis of this information can be related to indicators of coordination or dexterity.

Although it is true that the ABBT's graphycal interface has allowed to administer the test with minimal intervention of the therapist, it is also necessary to improve the detection performance of the counting blocks algorithm in future developments.

The subjective experience of the participants was favorable, being remarkable that all were able to complete the ABBT. The possibility of having a tool like the ABBT, that would allow to improve the assessment by focusing attention on the subject and not on the test, has been highlighted by the medical professionals. For example, the physician may detect if the individual performs some type of compensation to assist in the movement, such as leaning the trunk forward or forcing the shoulder. In this way, the rehabilitation therapy could be redirected to correct these conditions.

V. CONCLUSION

In this paper, we report the results of a pilot trials extension that presents the effectiveness of the ABBT, which must be improved in next works. The qualitative experiences of the subjets were positive. Also, counting with a low-cost automated system of assessment was positively highlighted by medical professionals. This further supports the feasibility of the use of automated systems in assessment of stroke physical rehabilitation.

REFERENCES

[1] Oña, Edwin D., Jardón Alberto, Balaguer Carlos. El "Automatizado Box & Blocks Test". Sistema automático de evaluación de destreza manual gruesa. *XXXVII Jornadas de Automática*, pp. 619-626, Madrid (2016). Accesit to the best works of Computer Vision.

[2] Van der Putten, J. J. M. F., et al. Measuring change in disability after inpatient rehabilitation: comparison of the responsiveness of the Barthel Index and the Functional Independence Measure. *Journal of Neurology, Neurosurgery & Psychiatry*, 66.4 (1999): 480-484.

[3] Saborowski, Maxine, and Ingrid Kollak. "How do you care for technology???Care professionals' experiences with assistive technology in care of the elderly. *Technological Forecasting and Social Change*, 93 (2015): 133-140.

[4] Coster, Wendy J. Making the best match: Selecting outcome measures for clinical trials and outcome studies. *American Journal of Occupational Therapy*, 67.2 (2013): 162-170.

[5] Mathiowetz, Virgil, et al. Adult norms for the Box and Block Test of manual dexterity. *American Journal of Occupational Therapy*, 39.6 (1985): 386-391.

[6] Hsiao, Chih-Pin, Chen Zhao, and Ellen Yi-Leun Do. The Digital Box and Block Test Automating traditional post-stroke rehabilitation assessment. *Pervasive Computing and Communications Workshops (PERCOM Workshops)*, 2013 IEEE International Conference on. IEEE, 2013.